

FACTORS WHICH AFFECT THE DRAINED WEIGHT AND OTHER CHARACTERISTICS OF HEAT-PROCESSED RED CHERRIES^a

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Despite the importance of drained weight in processed red cherries, knowledge concerning the factors which govern drained weight remains meager. Variations in drained weight commonly are attributed either to differences in growth conditions of the cherries or to variations in spray treatments. That other factors, however, may affect drained weight is shown by the results of the present study.

The study was conducted on a laboratory scale and the experiments were designed principally to investigate the causes for the variations in drained weight rather than to establish new procedures which might be applicable directly to commercial practice. The study showed that the drained weight of cherries might be raised or lowered by different pre-processing and processing treatments.

MATERIALS AND METHODS

In 1950, 1 lot of Montmorency cherries was picked from each of 2 orchards near Orrtanna, Pennsylvania. Lot A was picked very carefully with stems attached to the fruit; Lot B was bruised slightly in being picked without stems. About 8 hours after being picked, the cherries were placed in storage maintained at 2°C.(35°F.) and 90% relative humidity. They remained sound for a long period and served as uniform raw material for the experiments.

A rapid laboratory method for processing the cherries was devised. In each test 40 dry, uniform cherries were pitted with a portable pitter at a predetermined temperature [2°, 10°, or 24°C.(35°, 50°, or 75°F.)]. Each cherry was permitted to drain on a dry table top for about 3 minutes before being pooled with the other cherries and weighed. The cherries were then poured into a beaker containing an equal weight of boiling distilled water, brought to a boil, and boiled gently for 1 minute. Water lost through evaporation was replaced. Drained weight (cherries drained on an 8-mesh screen for 2 minutes) was measured after the cherries had stood for 24 hours. The results obtained by this method correlated satisfactorily with those of a standard method of canning.

Soluble solids were estimated with an Abbé refractometer, and firmness was measured with a pressure tester (6). The color of the cooked filtered juice was indicated by the percent transmittance in a 1-cm. cell, measured with a spectrophotometer, at a wavelength of 520 mμ. In some experiments cherries were bruised by being dropped 3 times from a height of 3 feet into a porcelain tray. The extent of this bruising approximated that observed in some commercially handled cherries.

RESULTS

Changes in cherries during storage. For the sake of brevity, only a few of the data are presented in this report. Despite shrinkage of the fresh cherries, the drained weight in grams of processed fruit recoverable from

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a constant number of fresh cherries increased steadily with the period of storage (Table 1). The increase was greater in the A than in the B cherries, whose original drained weight was relatively high. Meanwhile the cherries increased in soluble solids (percentage basis) and in firmness, showed almost no change in pitting losses (percentage basis), but decreased somewhat in acidity and in red color.

Drained weight as used here indicates the overall yield of processed cherries, since the drained weight is related directly to the weight of the original fresh cherries. On the other hand, the commonly used ratio of drained weight to freshly pitted weight does not indicate reliably the overall yield (observe columns 2 through 4 of Tables 1 and 2). The ratio takes into account neither the differences in pitting losses among various samples nor the changes in weight of cherries which occur between harvest and time of pitting. During this period cherries may either gain or lose weight.

Spoilage of the fresh cherries was negligible for the first 3 or 4 weeks, although after 8 weeks of storage about 10% of the B cherries were culls. Spoilage in lot A (stems attached) did not begin until after 7 to 8 weeks of storage. The cherries were not washed or given any special treatment before storage. Commercially handled fruit, however, probably would not remain sound if stored for 3 weeks at 2°C.

Increasing the drained weight. A number of treatments other than prolonged cold storage were found to result in an increase in the drained weight of the lot A cherries (Table 2). After the cherries had been in cold storage for 1 week, bruising them and permitting them to stand or to soak for several hours before being processed increased their drained weight. The bruising had little effect on the color of the processed cherries, although if bruised cherries were stored for more than about 24 hours at room temperature (24°C.), their color deteriorated. They remained relatively stable, however, if held at a low temperature (2°C.) in water or in a dilute calcium chloride solution. At the low temperature their pitting losses were minimized. The bruised cherries were less firm in the raw state but more firm in the processed state than were unbruised cherries.

After the fresh cherries (Lot A) had been stored for 60 days at 2°C. and their resultant drained weight had increased to a relatively high value, bruising had almost no effect on drained weight. Similar results were obtained with the cherries of Lot B (high drained weight) after a storage period of 16 days. It is believed that the slight bruising of the B cherries attendant with their picking was responsible in part for their high drained weight and for their lack of response to additional bruising.

Further studies were conducted in 1951 on 5 lots of cherries picked very carefully both with and without attached stems. All 5 lots initially had low drained weights and responded to bruising in a manner identical with that of Lot A. Another 2 lots, bruised slightly while being picked, had drained weights of intermediate value. The final 3 lots studied in 1951 were commercially handled cherries which were rather severely bruised. Their drained weights were uniformly high.

There were conditions, however, under which the bruising of cherries resulted in a lowering of the drained weight. In 1951, for instance, the bruising of carefully handled cherries just a few minutes before they were pitted and processed lowered their drained weight from 120.0 to 115.6 g. (average of 6 experiments with 3 lots of cherries). The bruising caused excessive loss of juice and tearing of cherries during the pitting operation. On the other hand, the drained weight of similarly bruised cherries which were stored in air or soaked in water for several hours after being bruised was 129.6 g. In addition, the loss from their pitting was comparatively small.

TABLE 1
Effect of storage in air at 2°C. on drained weight and other characteristics of red cherries

| Days stored | Weight of 40 fresh whole cherries g. | Drained weight of 40 processed pitted cherries g. | Ratio of drained weight to freshly pitted weight | Pitting loss % | Soluble solids in fresh juice % | pH of fresh juice | Compression of fresh cherries (firmness) % | Color, transmittance at 520 mμ of processed juice % |
|-------------|---|--|--|-------------------|------------------------------------|-------------------|---|--|
| Lot A | | | | | | | | |
| 5..... | 175 | 104 | 0.69 | 14.0 | 13.0 | 3.5 | 24.4 | 10 |
| 12..... | 174 | 105 | 0.71 | 14.4 | 13.5 | 3.5 | | 10 |
| 26..... | 172 | 108 | 0.75 | | 13.8 | 3.6 | | 12 |
| 40..... | 169 | 119 | 0.83 | 14.7 | 13.8 | 3.7 | 23.6 | |
| 59..... | 166 | 120 | 0.85 | 15.0 | 13.8 | 3.8 | 23.1 | 22 |
| 76..... | 163 | 127 | 0.92 | 15.0 | 13.8 | 4.0 | 22.1 | 27 |
| 101..... | 160 | 145 | 1.07 | 14.3 | 14.4 | 4.3 | 17.7 | 39 |
| Lot B | | | | | | | | |
| 12..... | 168 | 118 | 0.89 | 20.0 | 13.8 | 3.7 | 21.1 | 12 |
| 24..... | 165 | 117 | 0.88 | 20.1 | 14.0 | 3.8 | 20.2 | 11 |
| 60..... | 155 | 124 | 0.99 | 18.6 | 14.3 | 4.0 | 17.9 | 18 |
| 74..... | 152 | 129 | 1.03 | 18.4 | 14.3 | 3.9 | 16.0 | 40 |

TABLE 2
Effect of various treatments, including bruising and soaking in calcium chloride solution, on drained weight and other characteristics of red cherries, Lot A

| Treatment | Weight of 40 fresh whole cherries g. | Drained weight of 40 pitted processed cherries g. | Ratio of drained weight to freshly pitted weight | Pitting loss % | Soluble solids in fresh juice % | Compression of fresh cherries (firmness) % | Color, transmittance at 520 mμ of processed juice % |
|---|---|--|--|-------------------|------------------------------------|---|--|
| Original cherries, 2°C..... | 175 | 101 | 0.67 | 13.9 | 13.3 | 22 | 10 |
| Soaked in water for 24 hours at 2°C..... | 186 | 102 | | | 12.2 | 21 | 10 |
| Stored in air for 24 hours at 24°C..... | 171 | 106 | 0.73 | 15.3 | 14.0 | 22 | 10 |
| Bruised, stored in air for 24 hours at 24°C..... | 158 | 117 | 0.88 | 16.1 | 14.0 | 33 | 12 |
| Soaked in 0.2% CaCl ₂ for 24 hours at 24°C..... | 187 | 113 | 0.74 | 17.3 | 11.7 | 20 | 17 |
| Bruised, soaked in 0.2% CaCl ₂ for 24 hours at 24°C..... | 162 | 121 | 0.89 | 16.5 | 11.6 | 30 | 15 |
| Soaked in 0.2% CaCl ₂ for 24 hours at 2°C..... | 184 | 115 | 0.75 | 15.4 | 12.7 | 19 | 13 |
| Bruised, soaked in 0.2% CaCl ₂ for 24 hours at 2°C..... | 172 | 121 | 0.83 | 14.8 | 13.8 | 33 | 13 |

^cThe original weight of the 40 cherries used for each treatment was 175 g. Before treatment, all samples had been stored at 2°C. for 1 week.

It is apparent that the effects of bruising on drained weight depend partly on the extent of bruising, the time of bruising, the temperature and duration of the storage period after bruising, and the condition of the cherries at the time of bruising. Under the experimental conditions employed by Hills, Whittenberger, Robertson, and Case (3), bruising had no effect on the yield of final product. The bruising did, however, increase both the tenderometer reading and the ratio of drained weight to put-in weight of the canned cherries.

Another means of increasing the drained weight of the cherries (both Lots A and B) was to store them in air at 24°C. For instance, the storing of the Lot A cherries at this temperature for 24 hours increased their drained weight from 101 to 106 g. The increase was proportional to the length of the storage period for the first 2 or 3 days. Bruised fruit, however, did not keep satisfactorily at this temperature for more than about 24 hours.

Finally, drained weight was increased by soaking and processing the cherries in a dilute solution of calcium chloride (Table 2 and Figure 1). Calcium ions were effective at both 2° and 24°C. on both bruised and unbruised fruit. The increase was greater with cherries having a low drained weight (Lot A) than with fruit of high drained weight (Lot B). Most processing plants use hard water which contains calcium for the soaking and canning of red cherries.

Decreasing the drained weight. Treatment of cherries with pectin extractants lowered their drained weight. In one experiment, processing the cherries in a dilute solution of ammonium oxalate decreased their drained weight by 33% (Figure 1). Prolonged heating had a similar effect. For example, cherries (Lot A) boiled for a few seconds, 10 minutes, and 30 minutes, had drained weights of 118, 107, and 101 g., respectively. However, after the raw cherries had become toughened by storage for 3 months, the length of the heating period had little effect on drained weight. As

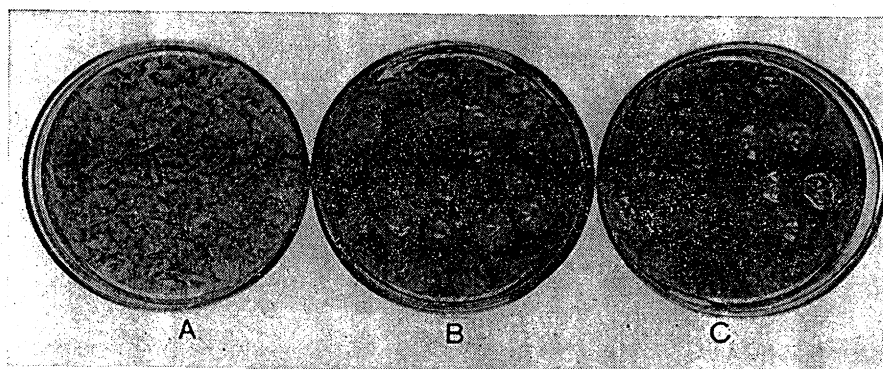


Figure 1. Effects of ammonium oxalate and calcium chloride on processed red cherries. A, Processed in 1.4% ammonium oxalate. Drained weight, 67 g. B, Processed in distilled water. Drained weight, 100 g. C, Processed in 0.5% calcium chloride. Drained weight, 115 g.

stated previously, the bruising of cherries (3 lots in 1951) lowered their drained weight if they were processed immediately after being bruised.

Miscellaneous observations on drained weight. Within each lot there was no relationship between the soluble solids content of raw cherries and the drained weight of processed fruit. In Lot A, for instance, cherries containing 11.5, 13.0, and 14.1% soluble solids had identical drained weights. Samples differing in soluble solids content were obtained by manually separating the cherries into three color groups (orange red, red, mahogany red). Similar results were obtained with the cherries in Lot B.

In some experiments cherries of both Lots A and B were separated into groups differing in total solids content by flotation of the raw cherries in brine solutions of different specific gravities. No apparent relationship between total solids content and drained weight was observed within either lot. The specific gravity method of grading, however, may be useful for predetermining factors other than drained weight. The correlation within each lot between specific gravity and soluble solids content and between specific gravity and color was good. Light colored cherries were separated quickly and conveniently from average to dark colored fruit. A minor limitation of this method of grading cherries was that the pits differed more widely in specific gravity than did the whole cherries.

Soaking the cherries (Lot A) in distilled water had little effect on the yield of final product (Table 2). Although unbruised cherries increased in weight by about 6% when soaked for 24 hours, this increase was not reflected in the final yield. The bruised cherries did not gain in weight when soaked.

Drained weight was dependent partly on the temperature of the cherries. The same cherries measured at 84°, 24°, and 4°C. (at 2-hour intervals) had drained weights of 113.8, 122.8, and 125.2 g., respectively.

The error involved in the measurement of drained weight was nearly as great as that incurred during all the other steps of sampling, pitting, and processing. For instance, the drained weight of the same 40 cherries was measured 5 times. After each measurement, the cherries and juice were recombined and permitted to come to equilibrium. In contrast with that of canned and stored cherries, the drained weight did not decrease linearly with each successive measurement, but varied in an irregular manner. The mean drained weight was 135.5 g. with a standard error of 0.41 g. On the other hand, the mean drained weight of 5 separately processed samples of the same cherries was 133.5 g. with a standard error of 0.47 g.

Comparison of methods. The results obtained by the rapid method of processing correlated well with those obtained by a standard method of canning, the coefficient of correlation between the ratios of drained weight to freshly pitted weight being +0.958 (Table 3). However, quantitative differences did exist. The rapid method was the more sensitive and magnified to a higher degree the differences in ratios of drained weight to freshly pitted weight among various samples.

The 2 sets of data of Table 3 are not strictly comparable. Although the results of the rapid method were obtained 24 hours after processing, those of the standard method were obtained after the cherries had been stored in cans for 8 months at 24°C. During storage canned cherries may undergo changes in color (1, 2), acidity (2), texture (2), and possibly in drained weight.

DISCUSSION

The collective data of this study permit the formulation of a hypothesis concerning the nature of drained weight. High drained weight in heat-processed cherries seems to be associated with a high degree of tissue cohesiveness, which in turn is dependent on the strength or heat stability of the intercellular cement. Microscopic examination reveals that from tissues exhibiting low drained weight, single intact cells and clusters of cells may slough off of their own accord or may be separated easily with a

TABLE 3
Drained weights obtained by rapid and standard methods of processing red cherries ^a

| Cherries from lot | Storage period of fresh cherries | Treatment after storage | Ratio of drained weight to freshly pitted weight | |
|-------------------|----------------------------------|---|--|------------------------------|
| | | | Rapid method | Standard method ^c |
| | <i>days</i> | | | |
| A | 26 | None | 0.741±0.0064 ^f | 0.822 |
| B | 29 | Soaked in water, 10°C., for 24 hours | 0.809 | 0.838 |
| B | 29 | Soaked in 30% sucrose for 24 hours | 0.814 | 0.884 |
| A | 39 | Processed at once after being pitted | 0.817 | 0.862 |
| A | 59 | None | 0.853±0.0031 ^f | 0.878 |
| | | Commercial cherries | 0.860 | 0.857 |
| A | 39 | Processed 5 hours after being pitted | 0.870 | 0.896 |
| A | 60 | Soaked in water, 2°C., for 24 hours | 0.877±0.0047 ^f | 0.897 |
| B | 24 | None | 0.881±0.0059 ^f | 0.890 |
| A | 61 | Stored at 24° and 4°C. for 1 day each | 0.913 | 0.911 |
| A | 61 | Bruised, air 24°C., water 2°C. | 0.974±0.0051 ^f | 0.921 |
| A | 74 | Stored at 24°C. for 1 day, 4°C. for 2 weeks | 1.022 | 0.967 |
| B | 27 | Stored at 24°C. for 2 days | 1.048 | 0.963 |

^aThe coefficient of correlation was +0.958.

^cCherries were processed to a central-can temperature of 90°C.(195°F.) in No. 2 tins.

^fStandard error, n = 5.

microneedle (Figure 2). This indicates that the intercellular cement is comparatively weak. On the other hand, single intact cells cannot readily be separated from freshly processed tissues showing high drained weight. When a cell is subjected to tension with a microneedle, its wall fractures before the intercellular cement fails.

In the present concept, then, the processed cherry may be looked upon as a cellulose sponge whose liquid-holding capacity is dependent on the maintenance of its cellular structure. Variations in soluble solids content of cherries otherwise identical should have little effect on drained weight, since the variations would not affect the intercellular cement and the cell membranes are no longer differentially permeable after processing. Our

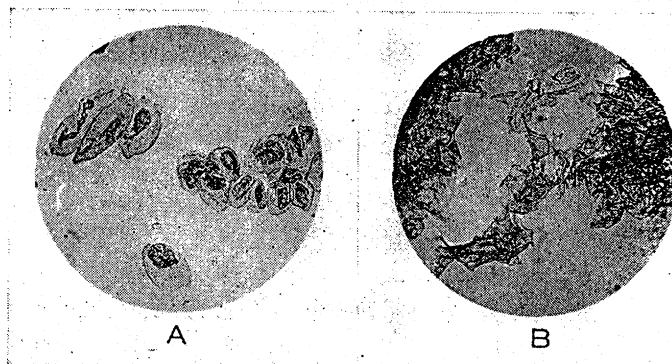


Figure 2. Photomicrographs of microdissected tissues of processed red cherries (29 X). A, Tissues of low drained weight. Single whole cells and small clusters of cells separate readily from the main body of tissue. B, Tissues of high drained weight. Cells fracture rather than separate when subjected to tension.

studies indicate that soluble solids data alone cannot be used reliably to predetermine drained weight. As a matter of coincidence, however, there may be a rough relationship between soluble solids content and drained weight of different lots of cherries, since soluble solids content under some conditions may be related to a more fundamental factor, the pectin-cellulose structure of tissues.

It might be expected, however, that agents which affect the intercellular cement (composed principally of pectic compounds) would also affect drained weight. Such is the case. The intercellular cement is weakened and drained weight is decreased by: 1, treating tissues with pectin extractants; 2, prolonged cooking of tissues; and 3, mechanical pressure (that is, placing a weight on the cherries during the measurement of drained weight). The pressure effect is proportionally greater in cherries of low drained weight (weak intercellular cement) than it is in cherries of high drained weight (strong intercellular cement). Permanent damage is done to the tissues of the former, but tissues of the latter recover.

On the other hand, the intercellular cement of freshly picked, unbruised cherries is strengthened and drained weight is increased by: 1, bruising combined with aging of tissues; 2, physiological aging or "conditioning" of tissues; and 3, treating tissues with calcium ions.

The manner in which bruising increases the strength of the intercellular cement or its capacity to resist degradation by heat is not clear. It is known, however, that bruising induces definite physiological responses and generally increases the rate of respiration. In cherries, the bruised tissues may be partially repaired and strengthened. The aging of tissues evidently results either in the strengthening of the intercellular cement or in the thickening of cell walls, or more probably, in both. In general, young tissues are more tender, fragile, and internally flexible than are similar old tissues. Our results are in agreement with the observation that aging and its effects occur more rapidly at a high temperature (24°C.) than at a low temperature (2°C.). The effect of calcium ions on the intercellular cement is well known (4, 5).

After being picked, cherries continuously undergo changes which affect their drained weight, even though they are given no experimental treatment. Of utmost importance in governing the changes are temperature of storage, duration of storage, and extent of bruising.

Unfortunately, the 3 factors listed above are difficult to control in large-scale experimental studies or in commercial practice. Pickers differ somewhat in the extent to which they bruise cherries, although they bruise nearly all samples rather severely. The picked cherries are permitted to stand for irregular periods and at various temperatures in the orchards or in trucks before being delivered to the processing plant. As a result, the principal variations in the drained weight of different lots of cherries may be caused by unnoticed differences in the manner of handling or storing the cherries rather than by differences in any other factor. In studies on the effects of maturity, spray treatments, soluble solids content, and soaking on drained weight, the different lots of cherries should be completely identical in extent of bruising and in post-harvest treatment. If the bruising and post-harvest treatments of all lots are sufficiently severe,

almost no differences in drained weights should be expected. On one hand, the treatments increase the drained weights to near maximum values; on the other hand, they cause losses in red color, acidity, tenderness, and possibly in flavor. In addition, the hardness of the processing water, which may change with the rainfall, may sometimes cause variations in drained weight.

The results presented in this report were confirmed in large measure by recent studies on 10 additional lots of cherries. The gap between the present findings and commercial practice, however, remains. Although it may be possible to account for variations in properties of processed fruit, effective control over the factors which cause the variations may be difficult.

SUMMARY

The successful storage of carefully picked and handled red cherries in air at 2°C. for 3 weeks suggested the possibility of lengthening the normally short processing season. During storage, the cherries underwent changes which increased their drained weight, firmness, and % soluble solids content. They showed almost no change in flavor and pitting losses, and decreased slightly in acidity and in red color.

From the collective data a general interpretation of the factors which affect drained weight was made. High drained weight was associated with a high degree of tissue cohesiveness, which in turn was dependent on the strength or heat stability of the intercellular cement. Microscopic studies showed that single whole cells could be separated easily from tissues of low drained weight but not from tissues of high drained weight. The processed cherry may be looked upon as a cellulose sponge whose liquid-holding capacity is dependent on the maintenance of its cellular structure. Factors which weaken the intercellular cement, such as prolonged cooking, extraction with pectin solvents, and mechanical pressure, decrease drained weight. Factors which strengthen the cement, such as post harvest aging or "conditioning" of the raw tissues, bruising combined with aging, and treatment with calcium ions, increase the drained weight.

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